STUDY ON THE INFLUENCE OF HEAT STRESS ON LACTATING HUNGARIAN SIMMENTAL COWS

Katalin Kitti KOMLÓSI, A. RIBÁCS

Szent István University, Institute for Irrigation and Water Management
Corresponding author: Ribacs.Attila@szie.hu

***Abstract:** The authors studied the effect of summer heat stress from Hungary on lactating Hungarian Simmental cattle. The study was carried out in July 2019, and involved 20 multiparous lactating cows. Each test day was characterized by a temperature-humidity index (THI1) for whose calculation at 15 hours – at the end of the warmest period – the data were registered. The cows water intake and milk production were measured, as well as the external body temperature, the pulse and respiratory rate of the animals were measured once a day, also at 15 hours. The relationship between the measured parameters and the THI1 value was investigated and the correlation between the parameters was studied. The data for each study day (n = 31; THI1 = 63-81) were used for the correlation analysis. The average value of the parameters measured on non-heat stress days (n = 12; THI1 = 63-68; hereafter NHS) and that on heat stress days (n = 17; THI1 = 69-75; hereafter HS) were compared. The cows' daily water intake (l/cow/day) was 79.4 ± 3.4 (NHS) vs. 84.4 ± 5.2 (HS) (+6.3%; p ≤ 0.01). The daily milk production (l/cow/day) was 13.2 ± 0.7 (NHS) vs. 11.9 ± 1.6 (HS) (-9.8%; p ≤ 0.01). The external body temperature (℃) was 38.4 ± 0.3 (NHS) vs. 38.8 ± 0.3 (HS) (p ≤ 0.002). The pulse (1/min) was 67.3 ± 2.6 (NHS) vs. 70.3 ± 2.3 (HS) (p ≤ 0.01). The respiratory rate (1/min) was 21.4 ± 0.6 (NHS) vs. 22.0 ± 0.9 (HS) (p ≤ 0.1 (NS)). Thus, even in the case of non-intensively bred dairy cattle Hungarian Simmental, which is well adapted to local conditions, an increase in drinking water consumption and a decrease in milk production can be detected already at 69-75 THI1 values. Water intake closely correlated to THI1 (r = 0.84; p ≤ 0.001). There is only a moderate correlation between external body temperature and THI1 (r = 0.47; p ≤ 0.01). Milk production was more closely related to THI1 (r = -0.84; p ≤ 0.001) than to external body temperature (r = -0.59; p ≤ 0.001). At the same time, respiratory rate and, in particular, pulse was strongly related to the external body temperature (r = 0.72; p ≤ 0.001 and r = 0.92; p ≤ 0.001).*

***Key words:** heat stress, THI, cattle, Hungarian Simmental, milk production*

INTRODUCTION

Climate change in recent decades (global warming) is most likely caused by human activity and will continue to be so for at least the next few decades. In the 21th century, higher maximum temperatures, more hot days and heat waves are expected almost everywhere on the mainland (IPCC, 2001 – http1). Using the data of the KSH (CSO) (http2), the average annual temperature increased over time (1985-2018) (r = 0.70; p ≤ 0.001), which can also be observed in Békéscsaba, a city located 31 km from the survey site *(Figure 1.)*.

The problems caused by heat stress nowadays not only affect tropical, subtropical and Mediterranean climates, however are also becoming more common during the summer months under the temperate climate.

Heat stress occurs when the balance between heat production and heat loss in cows is unhinged, meaning that they are no longer able to compensate for the increase in ambient temperature. For Holstein-Friesian cows, 25-26°C is the upper limit at which they can still maintain body temperature (BERMAN et al., 1985). BIANKA's (1965) studies on various breeds suggest that the effects of heat stress on the body are greatly influenced by the relative humidity of the air at temperature; at the same temperature but with different humidity, the milk production of cows was completely different. This is understandable, as the evaporation in the humid air is less effective for the cows to cool their bodies (WEST, 2003).

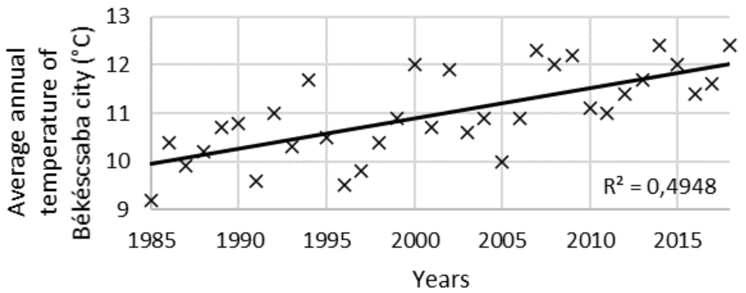

Figure 1. Increase of the average annual temperature in Békéscsaba city (Hungary, 1985-2018) (http2)

It is therefore very inaccurate to express the degree of heat stress in cows simply by the temperature. Instead, it was necessary to introduce a metric that is also related to the humidity of the air. The *temperature-humidity index (THI)*, calculated in different ways, serves this purpose. Some formulas of SOLYMOSI et al. (2010) collected:

THI1 = (0,15*Td + 0,85*Tw)*1,8 + 32
THI2 = (0,35*Td + 0,65*Tw)*1,8 + 32
THI3 = [0,4*(Td + Tw)]*1,8 + 32 + 15
THI4 = (0,55*Td + 0,2*Tdp)*1,8 + 32 + 17,5
THI5 = (Td + Tw)*0,72 + 40,6
THI6 = Td + 0,36*Tdp + 41,2

In which:

Td = dry temperature (°C)
Tw = wet temperature (°C)
Tdp = dew point (°C)

Of these, THI1 or THI2 is recommended in Hungary. The corresponding limit values are 68 (THI1) and 69 (THI2) (REICZIGEL et al., 2009; SOLYMOSI et al., 2010).

As the THI increases, the bovine rectal body temperature, respiratory rate, and pulse increase under the influence of heat stress; decreases in dry matter intake, growth rate, milk yield and fertility. According to some studies, the composition of milk may also change unfavourably (WEST, 2003; DAS et al., 2016; PRAGNA et al., 2017).

The lactation performance of cows is significantly influenced by *peripartum* climatic conditions; cows calved in winter produce more milk than the cows, which calved during summer. The difference is particularly striking during the first 2 months of lactation (MCDOWELL et al., 1976). Similar experiences are reported by TÓTH (2018); daily milk production in cows which calved during heat stress periods was significantly lower than in non-heat stressed calving cows. However, no significant difference was found between milking results on heat stress and non-heat stress production days. In contrast, INGRAHAM (1979) and RAVAGNOLO et al. (2000) observed a decrease in milk yield as the THI increased.

Domestic studies of TÓTH (2018) also pointed out that *peripartum* heat stress weakens the general resistance of cows, so that some diseases, which are typical at the beginning of lactation, may become more common (mastitis, ketosis). So, in addition to the decrease in milk yield and possibly content, the health of the livestock has to be considered, which further reduces the profitability of production. Therefore, protecting cattle against heat stress is not only an animal welfare issue.

BERMAN et al. (1985) found that Holstein-Friesian cows need to use cooling strategies that minimize body temperature, when this rises above 25°C. The production of cows, especially in countries with warm and humid climates, can only be maintained through the continuous development of cooling technologies (shielding, ventilation, wetting), nutritional formulations and selection for heat tolerance (WEST, 2003).

It is extremely important to provide cows with unlimited drinking water of good quality and optimum temperature during heat days. Sufficiently cold (10°C) drinking water can effectively help reduce body temperature (WILKS et al., 1990), while higher temperature drinking water should be added to animals to achieve the same effect (ATRIAN and AGHDAM, 2012).

In our studies, we looked at the effects of heat stress in Hungary, during summer in Hungarian Simmental breed on the following aspects:

- drinking water intake of cows,
- daily milk production,
- physiological parameters (external body temperature, pulse, respiratory rate).

MATERIAL AND METHOD

The examinations in Hungary (in the Southern Great Plain, Békés County), was conducted between 1 and 31 of July 2019, on 20 Hungarian Simmental cows. The Hungarian Simmental is a dual-purpose breed that combines quality milk production (content) and meat production. In recent years, the breed has been used mainly for meat production, which, due to selection, has adapted well to Hungary's – often extreme – agro-ecological conditions (http4). All cows included in the study were *multiparous,* 47-170 days had elapsed since their last calving at the start of the study. (The farm has an average lactation length of 260 days.)

The cows received the following daily ration:

- 8 kg corn silage
- 3 kg grass hay
- 3 kg alfalfa hay
- 6.12 kg concentrates

The composition of concentrates:

- 49% corn
- 33% barley
- 16% soybean meal
- 2% feed supplement (with dextrose and calcium carbonate)

This feed ration, based on 650 kg body weight and 4.0% milk fat, theoretically covers the production of 14-15 kg milk. It has a moderate dry matter content (kg), a high proportion of fodder concentrate (about 50% of the net energy for lactation), but at the same time has an adequate crude fibre content (18% of the dry matter content) well suited to heat stress cows (WEST, 2003).

The drinking water was between 12 and 14°C, colourless and odourless, with no visible impurities. It was provided *ad libitum*. The cows used an automatic drinker, with a flow meter fitted with a refill line. At 6 pm each day, before the evening milking, was read how much the group had consumed in the last 24 hours. The daily water intake was converted to 1 cow.

Animals were milked twice daily at 7 and 18 hours. The bulk milk was weighed and the daily milk production was converted to 1 cow.

The animals' external body temperature, pulse, and respiratory rate were individually measured once daily at 15 hours, that is at the end of the warmest period.

The external body temperature was measured non-contact with a Medisana TM-750 thermometer on the anus region, that is, on a body not covered with hair. The pulse was assessed by palpation of the jaw- or temple region and counted for 1 minute. The respiratory rate was also calculated by palpation with the palm pressed to the lateral chest (ribs) for 1 minute.

From the required meteorological data, the dry air temperature (Td) and the relative humidity of the air at the test site were determined simultaneously with a digital measuring instrument. The wet air temperature (Tw) was calculated from the measured data using a h-x calculator (online; http5). Among the temperature-humidity indices, THI1 was used, which was determined by the following formula (SOLYMOSI et al., 2010):

$$THI1 = (0{,}15*Td + 0{,}85*Tw)*1{,}8 + 32$$

Each test day was characterized by 1 THI1, for which data were always recorded at 3 pm. After that, a drop in temperature is expected, so the values will most likely always represent the *maximum* daily heat-load of the animals. One day was classified as heat stress if the resultant THI1 value was above 68.

Statistical data processing was performed in Microsoft Excel 2016. The relationship between the measured parameters and THI1, and the correlation between the parameters was investigated by calculation using the following formula:

$$r = \sum(x-\bar{x})*(y-\bar{y}) / \sqrt{[\sum(x-\bar{x})^2*\sum(y-\bar{y})^2]}$$

In which:

$\bar{x}$ and $\bar{y}$ = the average value of the data arrays

The data for each study day were used for the correlation analysis.

The mean values of non-heat stress and heat stress days were compared with the Student's t-test or, if the standard deviations were significantly different, with the Welch's t-test. The homogeneity of the standard deviations was checked by F-test. Data from the first and last test day, when THI1 > 78 was excluded from this analysis, were already classified as a higher level of heat stress than the range of 69-78, for which only 2 data were available.

RESULTS AND DISCUSSION

Meteorological characterization of the examined period

At 15 o'clock (dry) air temperatures ranged from 22.9 to 33.5°C, while relative humidity ranged from 31 to 64%. From the measured data, temperature-humidity indices (THI1) of 63-81 can be determined. The month as a whole is characterized by *mild heat stress*, as the average THI1 values were 70.

- 12 days (38.7% of the study period) were not heat stressed (THI1 ≤ 68).

- At 17 days (54.8%), THI1 ranged from 69-75.
- At 2 days (6.5%), the THI1 value was also above 78 (only occurring on the 1st and last day of the study period).

Daily water intake of cows during the study period

The water consumption of cows varied between 74.7 and 101.9 l/cow/day during the study period *(Figure 2.);* on non-heat stress days (n = 12) 79.4 ± 3.4; on heat stress days (THI1 = 69-75; n = 17) was 84.4 ± 5.2 l/cow/day. The difference was 5.0 l/cow/day (6.3%) ($p \leq 0.01$). In case of THI1 = 81 (n = 2): 96.4 and 101.9 l/cow/day water consumption. There was a strong positive correlation between daily drinking water consumption and THI1 (r = 0.84; $p \leq 0.001$).

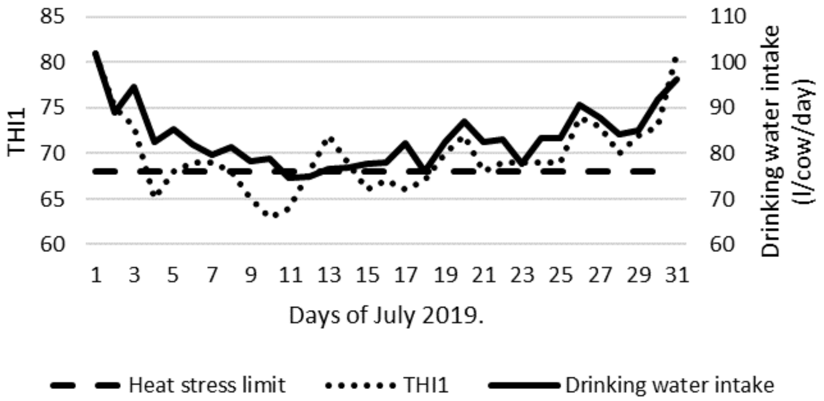

Figure 2. Range of the THI1 and daily water intake in examined period

The increase in water intake is partly explained by faster evaporation, which plays an important role in cooling the body, so it is part of the control against heat stress. However, it has long been known that e.g. in hot weather sheep consume significantly more drinking water than minimal requirement of intermediate metabolism and the evaporation (BLAXTER et al., 1959). SILANIKOVE (1989) observed an increase in rumen water in cows exposed to heat stress. RICHARDS (1985) also reported a temporary increase in body weight of dairy cows as a result of heat stress. He explained this phenomenon with increased water intake, which increases the total water content of the body. The high specific heat of water allows for the temporary storage of heat that a cow can release at night, when the air is cooler, much like a camel (SCHMIDT-NIELSEN, 1964).

The daily water consumption of dairy cows is influenced not only by the climatic conditions (temperature, humidity) but also by the dry matter intake, its chemical composition and the daily milk yield (MURPHY et al., 1983; KUME et al., 2010; KRAUSS et al., 2016).

Milk production of cows during the reference period *(Figure 3.)*

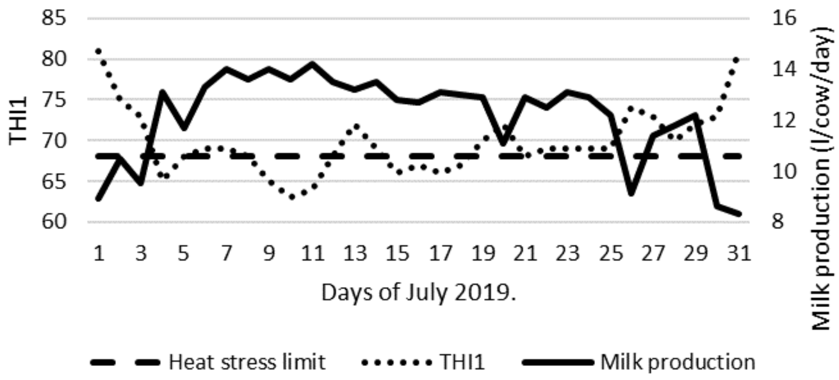

Figure 3. Range of the THI1 and daily milk production in examined period

Cows' milk production (l/cow/day) was in a strong negative relationship with THI1 ($r = -0.84$; $p \leq 0.001$). The closest correlation was observed when no delay was applied in the calculation (the same day's milk production was assigned to one day's THI1). In case of delay, the relationship weakened or disappeared:

- 1 day's delay $r = -0.55$; $p \leq 0.01$
- 2 days' delay $r = -0.47$; $p \leq 0.02$
- 3 days' delay $r = -0.22$; $p > 0.1$

On days when THI1 was above 68 (69-75), cows produced 1.3 litres (9.8%) less milk than THI1 ≤ 68 ($p \leq 0.01$). The daily milk production of the group was more closely related to the THI1 value ($r = -0.84$; $p \leq 0.001$) than the external body temperature of cows, measured during the hottest hours ($r = -0.59$; $p \leq 0.001$).

Our results are in agreement with REICZIGEL et al. (2009), according to which the effect of heat stress occurs immediately and even a single day of heat stress can cause 1.5-2 l/cow/day (5-10%) decrease in production. However, according to COLLIER et al. (1981) and SPIERS et al. (2004), the decline in milk production usually occurs after 24-48 hours.

In heat stress, the decline in milk production can be attributed to two reasons. On the one hand, the dry matter intake of cows is reduced, so the energy and nutrients for milk production are not available in the required quantities (POLSKY and KEYSERLINGK, 2017). On the other hand, the balance of endocrine system is disturbed, as a result the level of prolactin in the blood changes. PRAGNA et al. (2017) have shown that changes in prolactin concentration during dry periods may have a negative effect on milk production.

The dairy cattle are more exposed to heat stress than beef cattle; furthermore, the high-performance cows within a given breed are less able to withstand heat stress because their own heat production is significantly higher than that of low-performance cows or the dry cows (SPIERS et al., 2004; BERNABUCCI et al., 2010; RÍOS-UTRERA et al., 2013).

Some physiological parameters of cows during the study period

The **external body temperatures** of the cows at 15 hours varied between 38.1-39.1°C *(Figure 4.),* and showed a moderate positive correlation with THI1 ($r = 0.47$; $p \leq 0.01$). The average body temperature of the group on days 69-75 THI1 was nearly half a degree (0.4°C) higher (38.8 ± 0.3) than on non-heat stress days (38.4 ± 0.3; $p \leq 0.002$).

The mean **pulse** ranged from 64.0 to 73.4/min *(Figure 5.),* and only a weak to moderate correlation was found with THI1 at this parameter ($r = 0.40$; $p \leq 0.02$). At THI1 ≤ 68 and in the 69-75 range, only 3 beats/min were found (67.3 ± 2.6 vs. 70.3 ± 2.3), however the difference was significant ($p \leq 0.01$). The pulse showed a very strong positive relationship with *external body temperature* ($r = 0.92$; $p \leq 0.001$), much tighter than THI1.

The average **respiratory rate** of the cows was in the normal range every day and changed very little (between 20.4 and 23.5 breaths/min, *Figure 6.*). There was no statistically significant association with THI1 ($r = 0.28$; $p > 0.1$), but there was a strong positive association with cows' body temperature ($r = 0.72$; $p \leq 0.001$) and pulse ($r = 0.81$; $p \leq 0.001$).

BOURAOUI et al. (2002), with an increase in THI from 68 to 78, heart rate increased by 6/min, respiratory rate by 5/min, and rectal temperature increased by 0.5°C. The study was performed on Holstein-Friesian breeds and under Mediterranean climate. The tolerance of different breeds to heat stress – as already mentioned – varies, and this is manifested not only in milk production but also in physiological parameters. For example, according to the experience of MULLER and BOTHA (1993) in South Africa, the Jersey breed is much more resistant to heat stress than Holstein-Friesian.

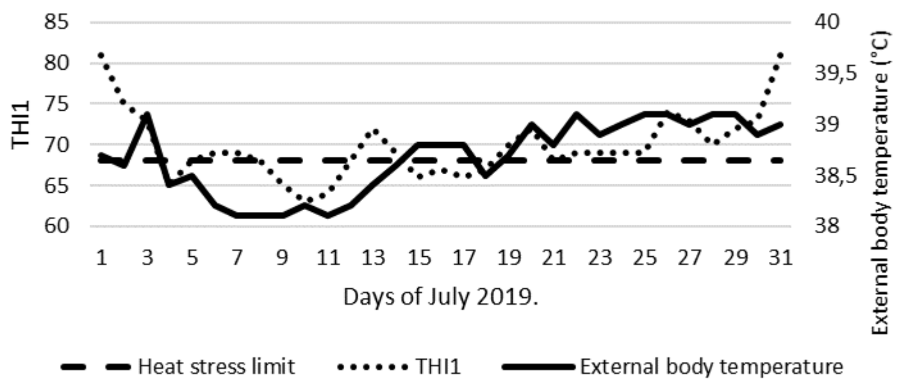

Figure 4. Range of the THI1 and external body temperature (15 h) in examined period

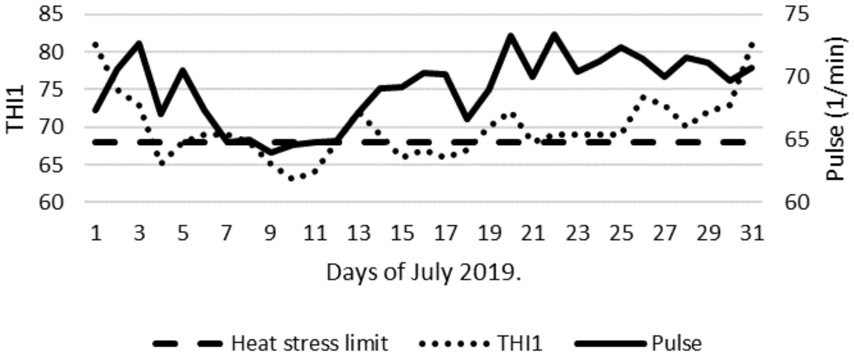

Figure 5. Range of the THI1 and pulse (15 h) in examined period

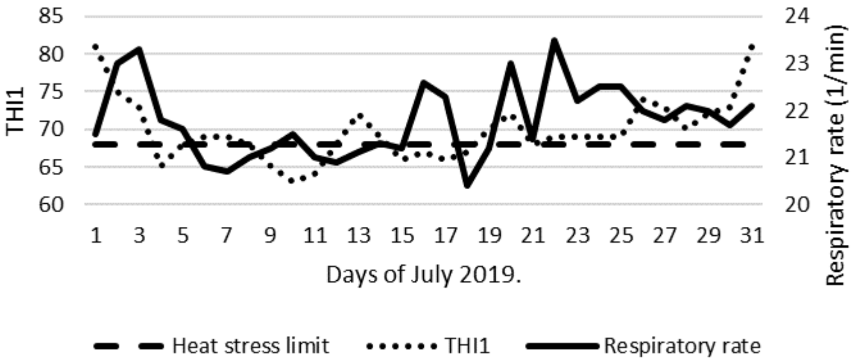

Figure 6. Range of the THI1 and respiratory rate (15 h) in examined period

MULLER and BOTHA (1993) pointed out that, contrary to our results, the pulse is less influenced by heat stress than respiratory rate. LEMERLE and GODDARD (1986) have reported similar results. Conflicting test results may be due to differences in breeds, climate, and possibly different rearing technologies. The studies referred were conducted in tropical or Mediterranean climates (New Guinea, South Africa). While MULLER and BOTHA (1993) had already observed a reduction in pulse at 32°C, in our case the temperature reached 32°C only for 5 days and reached a maximum of 33.5°C. The relative humidity was 46% on average over the whole reference period. When the temperature rose above 26°C, more than 60% of cases were associated with below-average (46%) humidity, thus drier air. This may have helped the cows to cool their bodies by evaporation, thus adapting well to adverse temperatures. This is probably the reason why the physiological parameters (respiratory rate, pulse rate) of the cows remained within the normal range.

Our results are summarized in *Table 1.*

Table 1.

Comparison of the results on non-heat stress days vs. heat stress days

THI1	63-68 (Non-heat stress)	69-75 (Heat stress)	Difference	
The number of days	n = 12	n = 17		
Drinking water intake (l/cow/day)	79.4 ± 3.4	84.4 ± 5.2	5.0 l (6.3%)	p ≤ 0.01
Milk yield (l/cow/day)	13.2 ± 0.7	11.9 ± 1.6	-1.3 l (-9.8%)	p ≤ 0.01
External body temperature (°C)	38.4 ± 0.3	38.8 ± 0.3	0.4°C	p ≤ 0.002
Pulse (1/min)	67.3 ± 2.6	70.3 ± 2.3	3.0/min	p ≤ 0.01
Respiratory rate (1/min)	21.4 ± 0.6	22.0 ± 0.9	0.6/min	p ≤ 0.1 (NS)

CONCLUSIONS

It is not uncommon in Hungary for THI1 to rise above 68 during summer months, so cows develop heat stress. In the case of non-intensively bred dairy cattle Hungarian Simmental, which is well adapted to local conditions, an increase in water consumption and a decrease in milk production can be detected already at 69-75 THI1 values. There is only a moderate correlation between *external* body temperature and THI1. Milk production was more closely related to THI1, than to external body temperature. At the same time, respiratory rate and, in particular, pulse was strongly related to external body temperature.

BIBLIOGRAPHY

ATRIAN, P. – SHSHRYAR, H. A. (2012): Heat stress in dairy cows (A review). Research in Zoology, 7.

BERMAN, A. – FOLMAN, Y. – KAIM, M. – MAMEN, M. – HERZ, Z. – WOLFENSON, D. – ARIELI, A. – GRABER, Y (1985): Upper critical temperatures and forced ventilation effects for high-yielding dairy cows in a subtropical climate. J. Dairy Sci. 68:1488-1495.

BERNABUCCI, U. – LACETERA, N. – BAUMGARD, L. H. – RHOADS, R. P. – RONCHI, B. – NARDONE, A. (2010): Metabolic and hormonal acclimation to heat stress in domesticated ruminants. Animal, 7:1167-1183.

BIANCA, W. (1965): Reviews of the progress of dairy science. Section A. Physiology. Cattle in a hot environment. J. Dairy Res. 32:291-345.

BLAXTER, K. L. – GRAHAM, N. – WAINMAN, F. W. – ARMSTRONG, D. G. (1959): Environmental temperature, energy metabolism and heat regulation in sheep. II. The partition of heat losses in closely clipped sheep. J. Agric. Sci. (Camb.) 52, 25-40.

BOURAOUI, R. – LAHMAR, M. – MAJDOUB, A. – DJEMALI, M. – BELYEA, R. (2002): The relationship of temperature-humidity index with milk production of dairy cows in a Mediterranean climate. Animal Research, 51:479-491.

COLLIER, R. J. – ELEY, R. M. – SHARMA, A. K. – PEREIRA, R. M. – BUFFINGTON, D. E. (1981): Shade management in subtropical environment for milk yield and composition in Holstein and Jersey cows. J. Dairy Sci. 64:844-849.

DAS, R. – SAILO, L. – VERMA, N. – BHARTI, P. – SAIKIA, J. – IMTIWATI – KUMAR, R. (2016): Impact of heat stress on health and performance of dairy animals: A review. Veterinary World, 9:260-268.

INGRAHAM, R. H. – STANLEY, R. W. – WAGNER, W. C. (1979): Seasonal effects of tropical climate on shaded and nonshaded cows as measured by rectal temperature, adrenal cortex hormones, thyroid hormone, and milk production. Am. J. Vet. Res. 40:1792-1797.

KRAUSS, M. – DRASTIG, K. – PROCHNOW, A. – ROSE-MEIERHÖFER, S. – KRAATZ, S. (2016): Drinking and cleaning water use in a dairy cow barn. Water, 8:302.

KUME, S. – NONAKA, K. – OSHITA, T. – KOZAKAI, T. (2010): Evaluation of drinking water intake, feed water intake and total water intake in dry and lactating cows fed silages. Livestock Science, 128: 46-51.

LEMERLE, C. – GODDARD, M. E. (1986): Assessment of heat stress in dairy cattle in Papua new guinea. Tropical Animal Health and Production, 18:232-242.

MCDOWELL, R. E. – HOOVEN, N. W. – CAMOENS, J. K. (1976): Effect of climate on performance of Holsteins in first lactation. J. Dairy Sci. 59:965-971.

MULLER, C. J. C. – BOTHA, J. A. (1993): Effect of summer climatic conditions on different heat tolerance indicators in primiparous Friesian and Jersey cows. South African J. Anim. Sci. 23:98-103.

MURPHY, M. R. –DAVIS, C. L. – MCCOY, G. C. (1983): Factors affecting water consumption by Holstein cows in early lactation. J. Dairy Sci. 66:35-38.

POLSKY, L. – KEYSERLINGK, M. A. G. (2017): Invited review: Effects of heat stress on dairy cattle welfare. J. Dairy Sci. 100:8645-8657.

PRAGNA, P. – ARCHANA, P. R. – ALEENA, J. – SEJIAN, V. – KRISHNAN, G. – BAGATH, M. – MANIMARAN, A. – BEENA, V. – KURIEN, E. K. – VARMA, G. – BHATTA, R. (2017): Heat stress and dairy cow: Impact on both milk yield and composition. International J. Dairy Sci. 12:1-11.

RAVAGNOLO, O. – MISZTAL, I. – HOOGENBOOM, G. (2000): Genetic component of heat stress in dairy cattle, development of heat index function. J. Dairy Sci. 83:2120-2125.

REICZIGEL J. – SOLYMOSI N. – KÖNYVES L. – MARÓTI-AGÓTS Á. – KERN A. – BARTYIK J. (2009): A hőstressz okozta tejtermelés-kiesés vizsgálata hőmérséklet-páratartalom indexek alkalmazásával. Magyar Állatorvosok Lapja, 131:137-144.

Richards, J. I. (1985): Milk production of Friesian cows subjected to high daytime temperatures when allowed food either ad lib or at nighttime only. Trop. Anim. Health Prod. 17:141-152.

RÍOS-UTRERA, Á. – CALDERÓN-ROBLES, R. C. – GALAVÍZ-RODRÍGUEZ, J. R. – VEGA-MURILLO, V. E. – LAGUNES-LAGUNES, J. (2013): Effects of breed, calving season and parity on milk yield, body weight and efficiency of dairy cows under subtropical conditions. J. Animal and Veterinary Advances, 5:226-232.

SCHMIDT-NIELSEN, K. (1964): Desert animals: Physiological problems of heat and water. Clarendon Press, Oxford.

SILANIKOVE, N. (1989): Role of the rumen and saliva in the homeostatic response to rapid re-hydration in cattle. Am. J. Physiol. 256:816-821.

SOLYMOSI N. – TORMA CS. – KERN A. – MARÓTI-AGÓTS Á. – BARCZA Z. – KÖNYVES L. – REICZIGEL J. (2010): Az évenkénti hőstresszes napok számának változása Magyarországon a klímaváltozás függvényében. 36. Meteorológiai Tudományos Napok, Magyar Tudományos Akadémia, november 18-19. Vid. Webography: http3.

SPIERS, D. E. – SPAIN, J. N. – SAMPSON, J. D. – RHOADS, R. P. (2004): Use of physiological parameters to predict milk yield and feed intake in heat-stressed dairy cows. J. Thermal Biology, 29:759-764.

TÓTH V. (2018): Hőstressz hatása tejtermelő tehenek tejtermelésére egy hazai nagyüzemű szarvasmarha telepen. Diplomamunka, Állatorvostudományi Egyetem, Budapest.

WEST, J. W. (2003): Effects of heat-stress on production in dairy cattle. J. Dairy Sci. 86:2131-2144.

WILKS, D. L. – COPPOCK, C. E. – LANHAM, J. K. – BROOKS, K. N. – BAKER, C. C. – BRYSON, W. L. – ELMORE, R. G. – STERMER, R. A. (1990): Responses of lactating Holstein cows to chilled drinking water in high ambient temperatures. J. Dairy Sci. 73:1091-1099.

http1: https://www.met.hu/eghajlat/eghajlatvaltozas/hatasok-alkalmazkodas/ Download: 12.02.2020

http2: https://www.ksh.hu/docs/hun/xstadat/xstadat_eves/i_met002a.html Download: 12.02.2020
http3: https://www.met.hu/doc/rendezvenyek/metnapok-2010/13_Solymosi.pdf Download: 26.06.2019
http4: http://www.magyartarka.hu/tartalom/tenyesztes/tenyesztesi_program.pdf Download: 19.02.2020
http5: http://www.bausoft.hu/php/hx/hxCalc.php Download: 01.07.2019